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NASA CR-160156

MCR-78-613
(Issue 3)

Contract
NAS9-15613

March, 1979

STUDY OF SAMPLE DRILLING TECHNIQUES FOR MARS SAMPLE RETURN MISSIONS

FINAL REPORT

Prepared for:

National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas 77058

MARTIN MARIETTA

Denver Division
Denver, Colorado 80201

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FOREWORD

This report is submitted in accordance with the requirement of NASA Contract NAS9-15613, Article XIII, Item 2, Final Report. It includes a summary of the work accomplished during the period of performance of the program.

The program was performed under the technical guidance of Dr. Jeffrey L. Warner and Dr. Uel S. Clanton of the NASA Johnson Space Center.

Appreciation is extended to Dr. James Gliozzi and Mr. Merton L. Clevett of Martin Marietta who assisted with the performance of this program.

D.S. Crouch

D. S. Crouch, Study Manager
Martin Marietta Aerospace

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CONTENTS (Concluded)

1.0 INTRODUCTION AND SUMMARY

1.1 Contract Requirements and Schedule

This eight-month study contract with a task value of approximately 4-1/2 manmonths was initiated on June 15, 1978, and is scheduled to complete on February 5, 1979. The primary purpose of the study was to perform a *preliminary survey* of the planetary scientific community to determine potential drill sampling (coring) requirements of a Mars sample return mission tentatively scheduled to be performed during the mid-1980's.

Other requirements of the program included the following:

1) Initiation of a test coring program on a suite of rocks which simulate the physical properties of the porous rocks observed on the Martian surface;

2) Evaluation of drill parameters such as core barrel diameter, thickness, rotation velocities, etc, which minimize fragmentation of porous rocks;

3) Evaluation of a potential technique for transferring the core barrel and sample to a sample return container.

The eigh-month schedule for performance of the program is illustrated in Table 1-1. The relatively long time period allowed for performance of this small contract was to permit sufficient response time from the scientific community.

1.2 Program Summary

A relatively large segment of the planetary scientific community was selected for the core sampling requirements survey. A questionnaire-type form and cover letter was prepared and submitted to approximately 2300 individuals which has resulted in 92 responses to date. A wide variety of scientific interests was expressed by the responding scientists. A summary of the responses is provided in Section 2.0 of this report.

A preliminary test coring program was initiated using commercial drilling equipment. Parametric drilling data were acquired and compared with data on file from the Martin Marietta Lunar Surface Drill Program performed in support of the Apollo project. It was determined that the power operating efficiency (energy per unit volume of drilled rock) of the Apollo drill was higher than the smaller and lower power commercial drill used for this program. Previous analyses and tests have indicated that scaling down of a lunar-drill size machine to a smaller machine for use on the Martian surface may not be an appropriate approach. Core recovery in both regolith and consolidated rock will decrease significantly if the core diameter is reduced

Table 1-1 Program Schedule

TASK NUMBER	MONTHS AFTER GO-AHEAD							
	1	2	3	4	5	6	7	8
1. Scientific Community Consultation								
• Prepare Questionnaire	—Δ							
• NASA Approval	Δ							
• Questionnaire to Scientists		—Δ						
• Responses			——Δ					
2. Initiate Test Program								
• Receipt of GFE Rocks	Δ				Δ			
• Acquire/Assemble Drill Equipment	——	—Δ						
• Test Setup and Checkout		——Δ						
3. Evaluate Coring Parameters			——	——	——	——Δ		
4. Handling of Disaggregated Core								
• Design Studies					——	——	——Δ	
• Test Evaluation							——Δ	
5. Study Outputs								
• Informal Reports			Δ			Δ		
• Final Report								—Δ
• Technical Briefing at JSC								Δ

significantly below approximately 1.9 centimeters. Additionally, core drilling in rock requires that a minimum *threshold* of energy per unit area (core bit annulus) be provided in order to penetrate the rock material. The results of this phase of the study are presented in Sections 3.0 and 4.0.

The final task of the program was to illustrate an approach for a Mars roving vehicle-mounted drill system capable of depositing core samples into a sample return container. This technique was accomplished by construction of a simple rover and drill mockup to demonstrate a potential system approach. The results of this phase of the study are presented in Section 5.0.

Recommendations for follow-on tasks are presented in Section 6.0.

2.0 SCIENTIFIC COMMUNITY REQUIREMENTS SURVEY

2.1 Survey Form

A simple one-page form was generated for submittal to members of the planetary scientific community. This form requested information regarding the nature of the proposed scientific experiments to be performed on the returned samples, types of core samples required (i.e., rock or regolith), geometry of the returned samples, special requirements, etc. These forms, along with appropriate cover letters from Dr. Michael B. Duke (Chief of the Lunar and Planetary Sciences Division at the NASA Johnson Space Center), and Mr. D. S. Crouch, the Martin Marietta Program Manager, were submitted to approximately 2300 members of the planetary scientific community. The listing for these scientists and engineers was provided by the Johnson Space Center. A copy of the form and letters used for this survey is provided in Appendix A.

2.2 Survey Results

A total of 92 responses to the questionnaire have been received to date. Of these responses, 62 responded directly to the potential core sample requirements for both particulate and rock material. A breakdown of these responses at *this level* includes the following:

13 individuals interested in *rock cores* only;

19 individuals interested in *particulate cores* only;

30 individuals interested in both *rock* and *particulate* cores.

A small number of responding individuals expressed a specific interest in sampling of permafrost in the polar regions and most of these individuals were rather strong in their convictions. It is anticipated that additional polar sample requests would have been received if the survey form and background letters had addressed the possibility of a polar-roving vehicle. Although only six individuals expressed an interest in biologically related experiments, this particular scientific community listing consisted primarily of geology-interested members. A similar sampling strategy survey of the biology-interested scientific community is being planned by Ames Research Center.

A variety of comments were received from the 30 individuals who did not respond directly to the potential core sample requirements. Approximately eight were *out of the space business, retired,* or had *no opinion*. The remaining 22 would be satisfied with *surface samples* (rock and particulate), or proposed other experiments either *indirectly related* to drilling (i.e., seismic sensors, water analyzer, in situ subsurface dielectric measurements), or indirectly related to the mission (i.e., solar wind collector).

Table 2-1 presents a summary of the 62 responses regarding rock core and regolith core requirements. It is interesting to note that 24 individuals requested that either (or both) a pressure and temperature control be provided for the return samples. These requests ranged from the difficult requirement of *complete maintenance* of Mars sample acquisition pressure and temperature to

Table 2-1 Survey Summary of Drill Core Requirements

Characteristic		Responses for Rock Cores	Responses for Regolith Core
Diameter	< 1 cm	2	2
	1 - 2.5 cm	36	34
	> 2.5 cm	2	6
	No Preference/No Comment	22	20
Core Depth	< 10 cm	10	4
	10 cm - 1 m	17	16
	1 - 2 m	3	10
	> 2 m	7	9
	No Preference/No Comment	25	23
Number of Holes	< 5	16	21
	5 - 15	17	14
	> 15	5	7
	No Preference/No Comment	24	20
Separation Distance	< 3 m	7	4
	3 - 500 m	11	9
	> 500 m	10	18
	No Preference/No Comment/ Real Time Judgment	34	31
Number of Samples	< 5	8	13
	5 - 20	17	13
	> 20	11	13
	No Preference/No Comment	26	23
Size (Volume)	< 1 cc	19	21
	1 - 10 cc	13	12
	10 - 100 cc	3	2
	> 100 cc	2	4
	No Preference/No Comment	25	23
Special Requirements			
	• Maintain Temperature and/or Pressure Control	19	24
	• No Preference/No Comment	43	38

the rather lenient requirement of permitting temperature rises up to 500°C. Several other *special requirements* were requested and are not specifically listed in the table since they are obviously inherent with any future Mars sampling mission. These included requirements such as avoidance of terrestrial contamination, avoidance of sample mixing, sampling from each major unit, minimum sample disturbance, and photodocumentation of all sampling sites. Several responses requested that an "undisturbed" regolith sample be returned and techniques for providing such a sample were suggested.

Table 2-2 provides a summary of categories of proposed experiments to be performed on the returned samples or in-situ experiments using the core holes. The complete collection of responses has been provided to the NASA for their continued evaluation.

Table 2-2 *Survey Summary of Proposed Experiments*

Analysis Technique / Sample Type	RETURNED SAMPLE ANALYSES															IN-SITU ANALYSIS				
	Petrology/Petrography					Exo-biology		Mechanical/Physical Properties												
	Inorganic Chemistry (incl. volatiles)	Mineralogy (incl. phase equilib. thermodynamics)	Fabric/Texture/Grain Morphology	Trace Element/Isotopic Composition	Undefined	Organic Chemistry	Paleontology	Acoustic Velocity	Density	Strength	Stratification	Thermal	Electrical	Magnetic	Optical	Water	Density/Physical Properties	Inorganic Chemistry	Grain Morphology	Optical
Regolith	8	2	4	4	3	4	2	2	5	4	6	3	3	2	2	2	2	1	1	2
Rock	5	3	2	2			1	1	1	1		2	2							
Regolith/Rock	26	15	13	5	1	5	2				1			1			2			2

NOTE 1: The JSC-furnished listing used for this study primarily contained scientific community members who are interested in the geological aspects of the Mars mission; inputs from a biological requirements study being performed for Dr. R. S. Young of NASA Headquarters, Chief of Planetary Biology, by NASA Ames Research Center will be included at a later date.

NOTE 2: In addition to the in-situ measurements identified during sample collection, some investigators would like to see instruments emplaced in the vacant core holes. These experiments include seismic, electrical, and thermal conductivity.

NOTE 3: One investigator suggested using the transport vehicle from earth to Mars and return as an ideal platform for measuring the composition of the interplanetary medium outside of the earth-moon system.

3.0 TEST CORING PROGRAM

3.1 Rocks

A suite of NASA-furnished rocks, and rocks available at Martin Marietta were assembled for *initiation* of a test coring program. These rocks were basaltic in composition, and provided a range of drilling hardness and porosity.

3.2 Test Equipment

The rocks and test equipment used for this task are pictured in Figures 3-1, -2, and -3. Basically, the drilling system consisted of a small commercial rotary-impact drill (Black and Decker Model 5040) mounted to a vertical traversing support stand. Variations in drilling thrust were provided by adding weights to the traversing support fixture. The tests were conducted over a thrust range of 89 to 200 Newtons (20-45 lbs) which was chosen on the basis of a reasonable restraint capability for a projected advanced Mars mission rover. Commercial drill bits and lunar drill bits were used for the tests. The drill was powered by a variable transformer which permitted selection of drilling speeds over a range of approximately 200-900 rpm.

3.3 Results

Typical data acquired during these tests are illustrated in Appendix B. The commercial drill was operated in the following ranges:

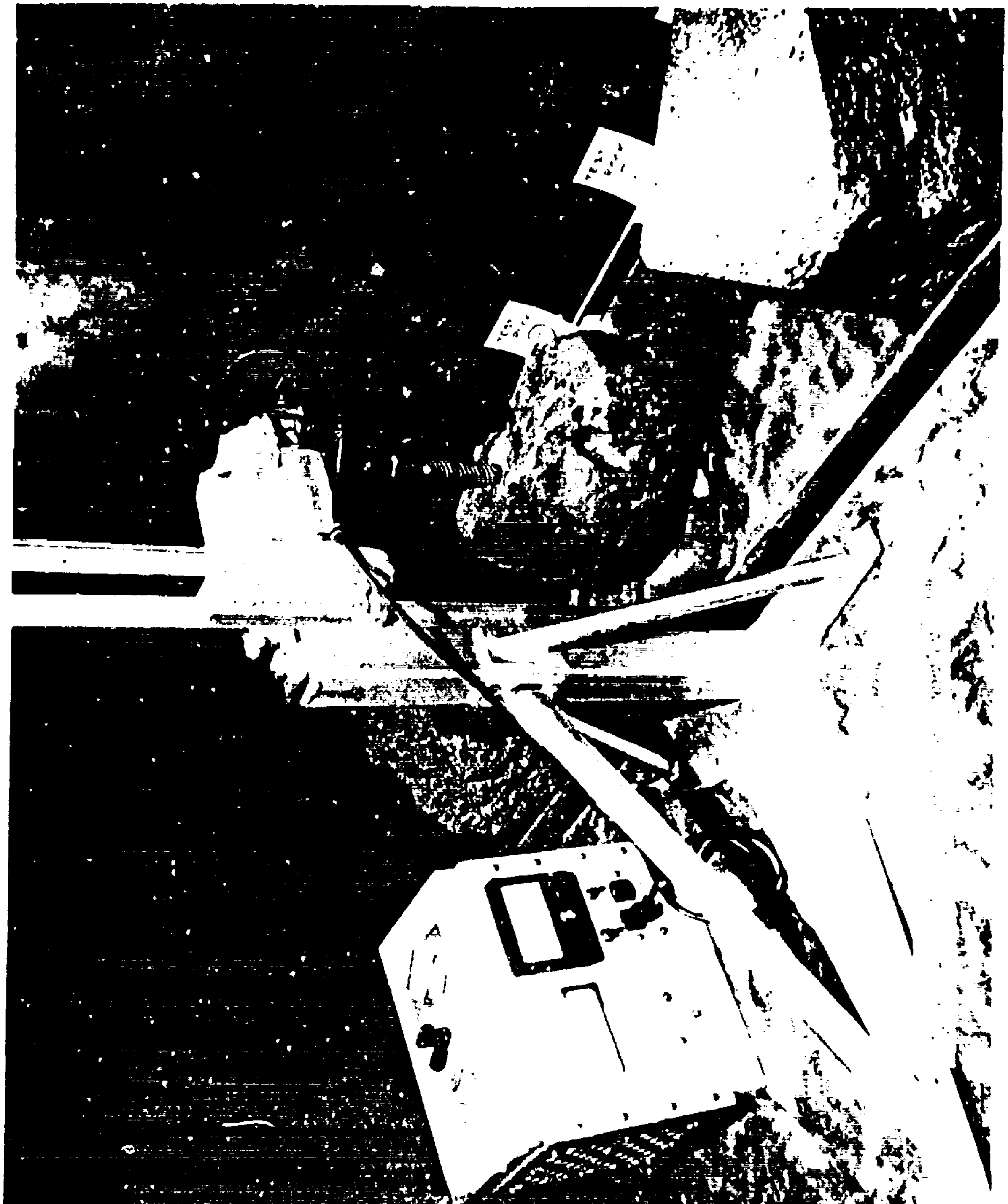
Power: 150 to 400 watts;

Thrust: 89 N (20 lb) to 200 N (45 lb);

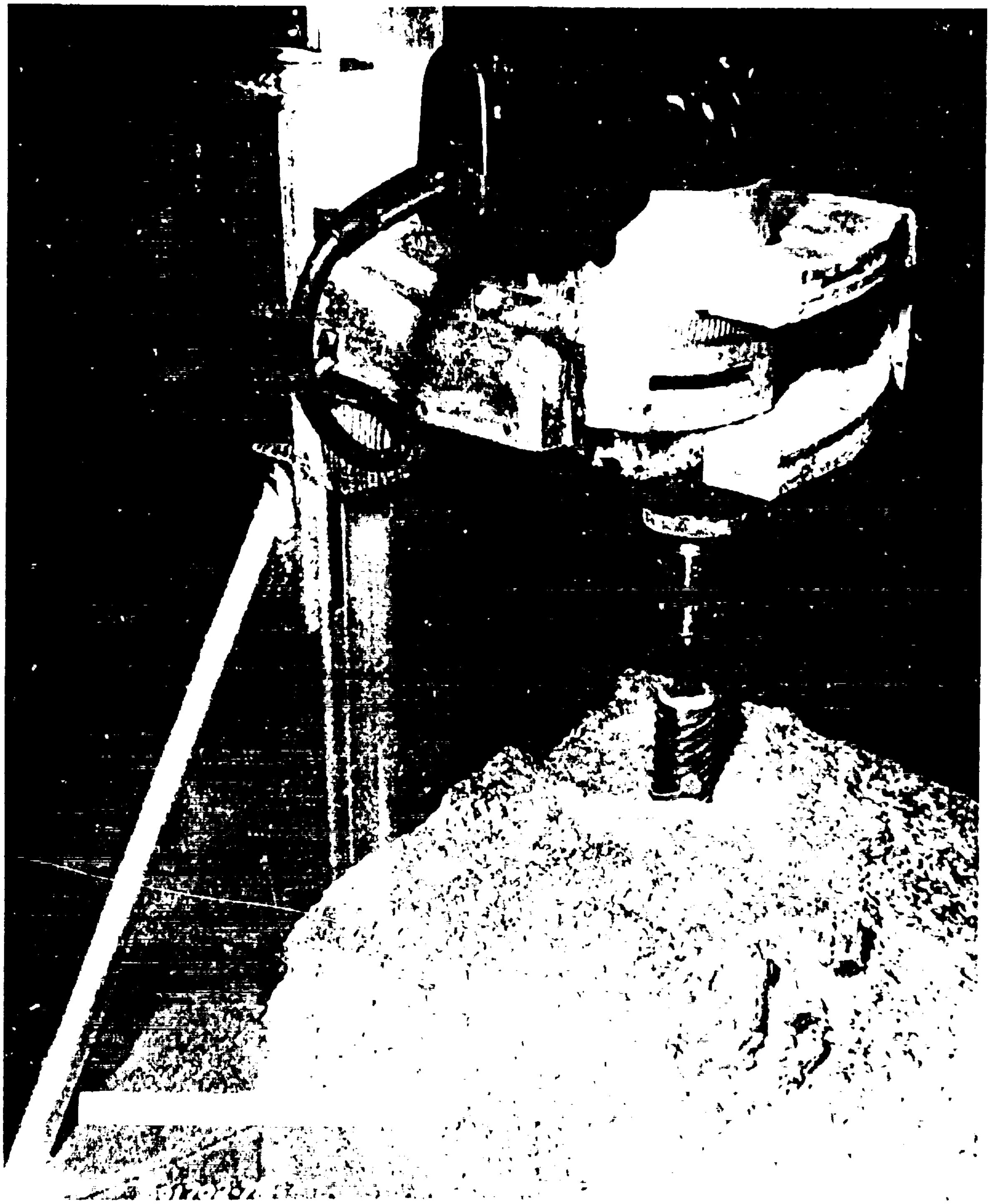
Speed: Approximately 150-900 rpm.

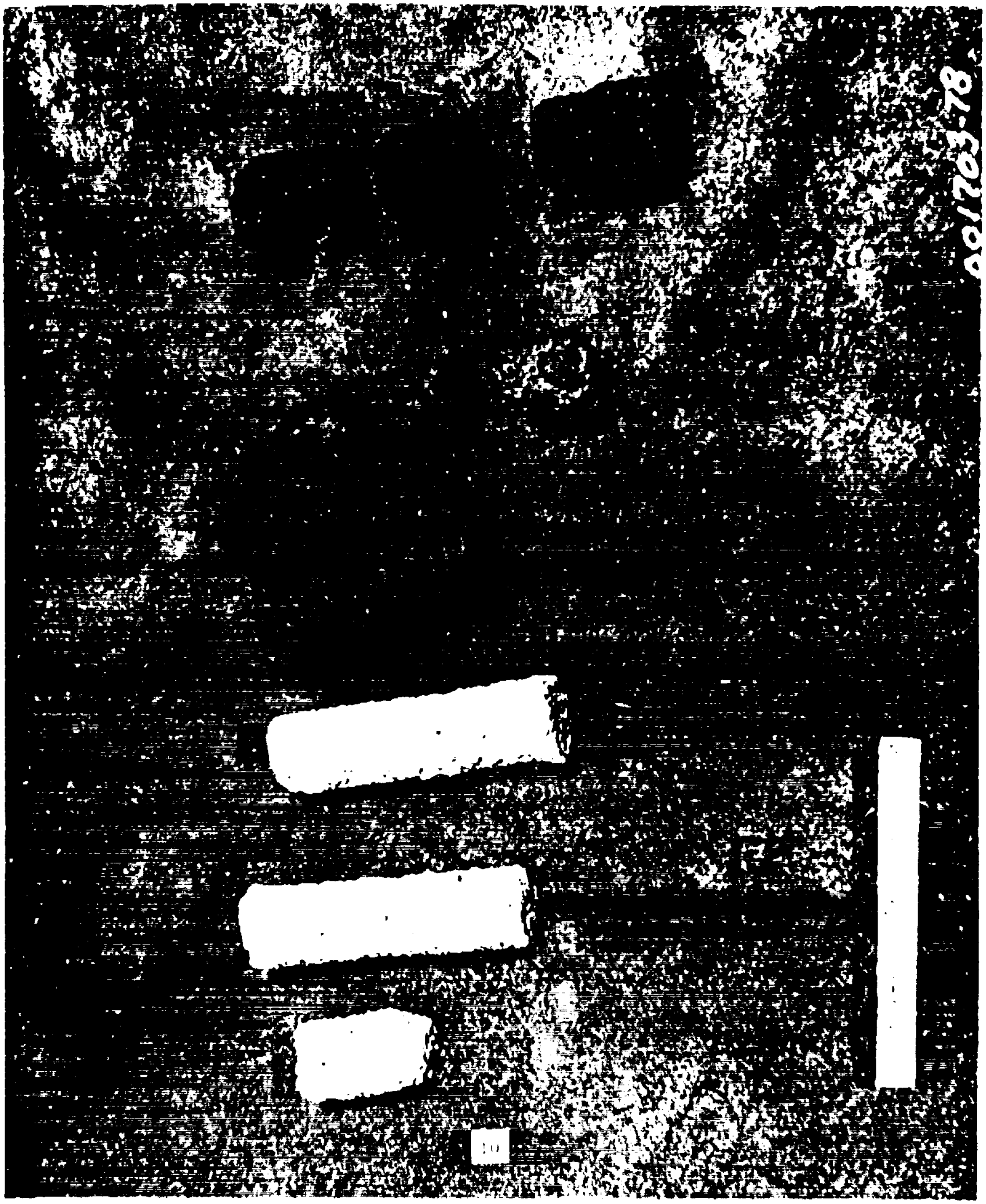
The power operating performance of the commercial drill was less than that attained for comparable drilling tests with the Apollo drill. As an example, the best drilling efficiency attained with the commercial drill and lunar drill 1.9-centimeter core bit in vesicular basalt was approximately 1.7 watt-hr/cc (28 watt-hr/in.^{3}) compared to a typical 0.2 watt-hr/cc (3.5 watt-hr/in.^{3}) with the lunar drill. Typical drilling rates with the commercial drill were 0.6 cm/min. compared to 15 cm/min. with the lunar drill. Figure 3-4 illustrates typical cores produced during these tests.

The scope of this test was severely limited due to the fact that only *residual* commercial and Apollo Lunar Drill hardware was available. However, the data acquired combined with Lunar Drill data provides a baseline for subsequent, and more extensive, design and test evaluation.




TEST ROCK
B

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4.0 DRILL DESIGN PARAMETERS

4.1 Background

The preliminary selection of a rotary-percussion drill system for the Mars sample return mission inclusive of the drill design parameters was primarily based on extensive previous efforts performed by Martin Marietta in support of the Apollo Lunar Surface Drill program. References 1 through 9 represent a partial listing of documents which were prepared during an eight year period of study, design, and development, which culminated with the successful operation of astronaut-operated lunar drills during Apollo missions 15, 16, and 17.

During the course of the early drilling technique studies, both *rotary* and *rotary percussion* systems were considered, and prototype drills were designed and tested. The results of these studies *clearly* revealed that the rotary-percussion system would be required to meet the constraints of the early Apollo missions. The results of these tradeoffs can be stated in simple terms as follows:

Drilling Technique	Advantages	Disadvantages
Rotary Diamond	Simpler mechanization Lighter weight Less power	Requires bit coolant (gas flow) Requires high drilling thrusts Requires efficient cuttings removal system Poor regolith core recovery
Rotary Percussion	No bit coolant Lower drilling thrusts Less sensitive to cuttings removal system Good regolith core recovery	Complex mechanization Heavier More power

The rotary-percussion system was selected *primarily* because of the lower drilling thrust requirements and because a mechanical spiral flute system could be used for drill cuttings removal. The rotary-diamond system would have required an open-loop gas flow system to cool the bit and remove the drill cuttings.

A *significant effort* was also expended during the Apollo drill program to optimize the rotary-percussion drill electromechanical design, and the design of the tungsten carbide core bits in order to provide a power-efficient system. An advanced state-of-the-art electric motor design was used, and numerous mechanical design innovations were employed to minimize frictional losses in the various drill mechanisms. Numerous core bit designs were fabricated and tested with variations in cutting kerf, number of carbides, carbide geometry, and carbide hardness before the final design was selected for the Apollo mission. The resultant optimized rotary-percussion drill system for Apollo was considerably more power-efficient than any commercial drill systems which existed at that time.

The drill system parameters summarized in the following paragraphs resulted primarily from Apollo Lunar Drill data extrapolation.

4.2 Core Bit and Extension Tubes

The design goal for the Mars drill core bit (and extension tubes if required) is to provide a design which will acquire a reasonably consolidated core(s) from porous rocks at a minimum power. The rotary-percussion type system is anticipated to be the most adaptable to meet the Mars rock drilling constraints of minimum power, thrust, and complexity. Acquiring a continuous core from extremely porous basaltic rock (i.e., porosities approaching 40-50%) would probably require at least a 5 to 8 centimeter diameter core bit to preclude intermittent fracturing of the core. Additionally, intentional "breaking" of such a large diameter core sample from the parent rock can be an exceedingly difficult task within the constraints of a Mars automated mission. Therefore, a reasonable compromise is to provide a smaller diameter core bit which will result in some core fragmentation as shown in Figure 3-4. The degree of fragmentation will depend on the porosity percentage and fragility of the parent rock.

A minimum wall thickness core bit and extension tube design is illustrated in Figures 4-1 and 4-2. This design will produce a 1.9-centimeter diameter core which is within the range requested by the majority of responses received from the scientific community survey. Minimum wall thickness core bits coupled with minimum width tungsten carbide tips are desirable to minimize the power requirements. The power required for drilling is directly proportional to the area of the annulus produced by the bit during the coring process. The configuration shown in Figure 4-1 results in a cutting annulus area of 2.51 cm^2 (0.389 $in.^2$).

4.3 Drilling Parameters

The majority of responses received from the scientific community requested that the length of the rock cores be in the range of 10 centimeters to 1 meter. *Rock coring* rather than *regolith coring* will size the drill in this application. Therefore, the nominal operational parameters of the lunar drill are applicable which include the following:

Core Bit Rotation Rate: 280 rpm;

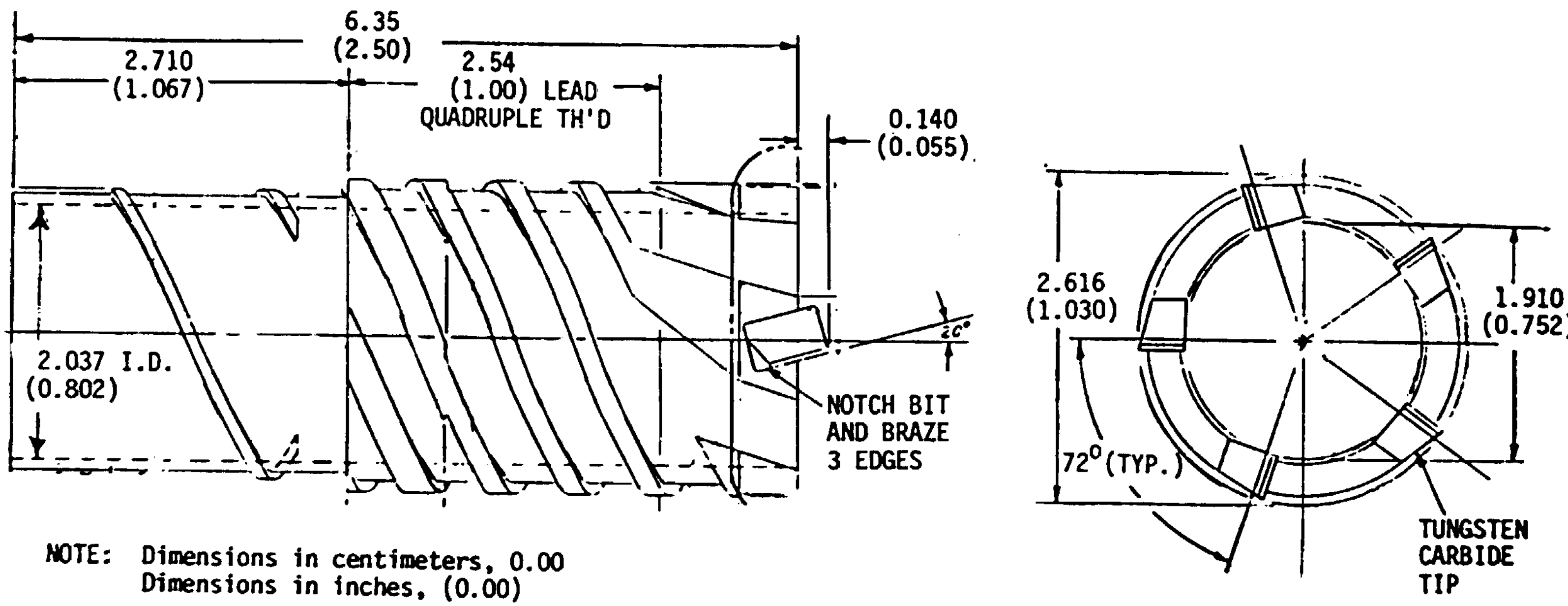
Percussive Energy: 440 N-cm (39 in.-lb);

Nominal Percussion Rate: 2,270 impacts/min.;

Impacts per Bit Revolution: 8.1:

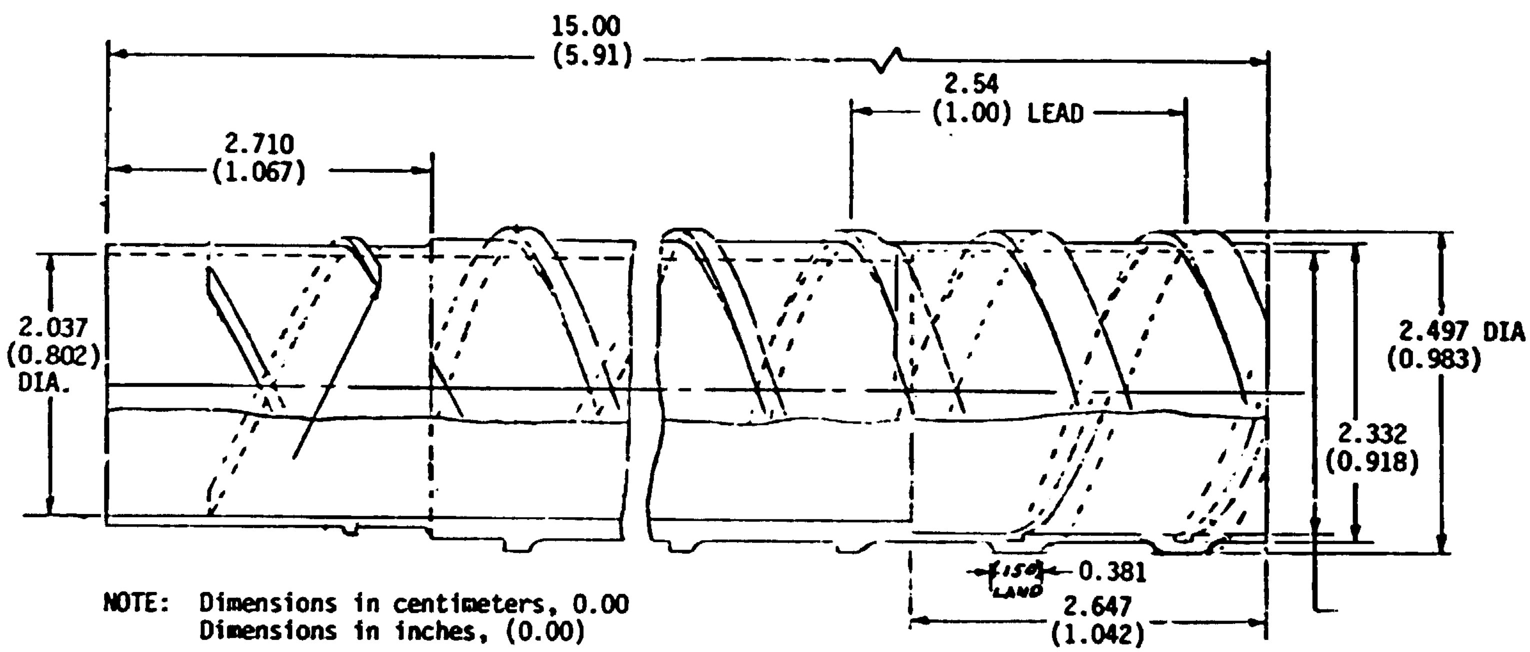
Power Requirement: 450 watts.

Figure 4-3 and 4-4 illustrate the power drilling efficiency and penetration rates which can be anticipated from a system incorporating these parameters.



NOTE: Dimensions in centimeters, 0.00
Dimensions in inches, (0.00)

Figure 4-1 Mars Drill Core Bit



NOTE: Dimensions in centimeters, 0.00
Dimensions in inches, (0.00)

Figure 4-2 Core Bit Extension Tube

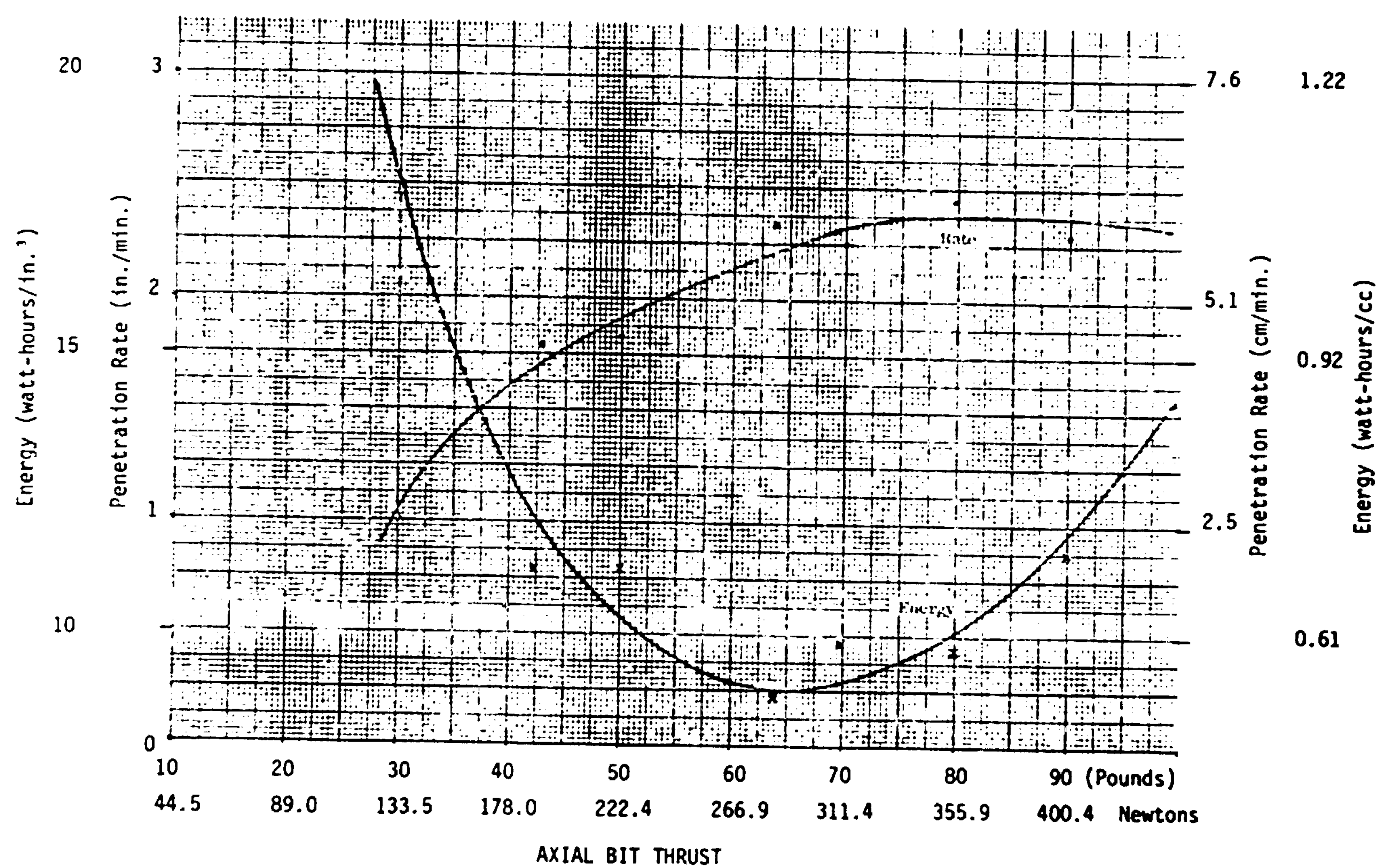


Figure 4-3 Projected Mars Drill Performance - 5% Porosity Basalt

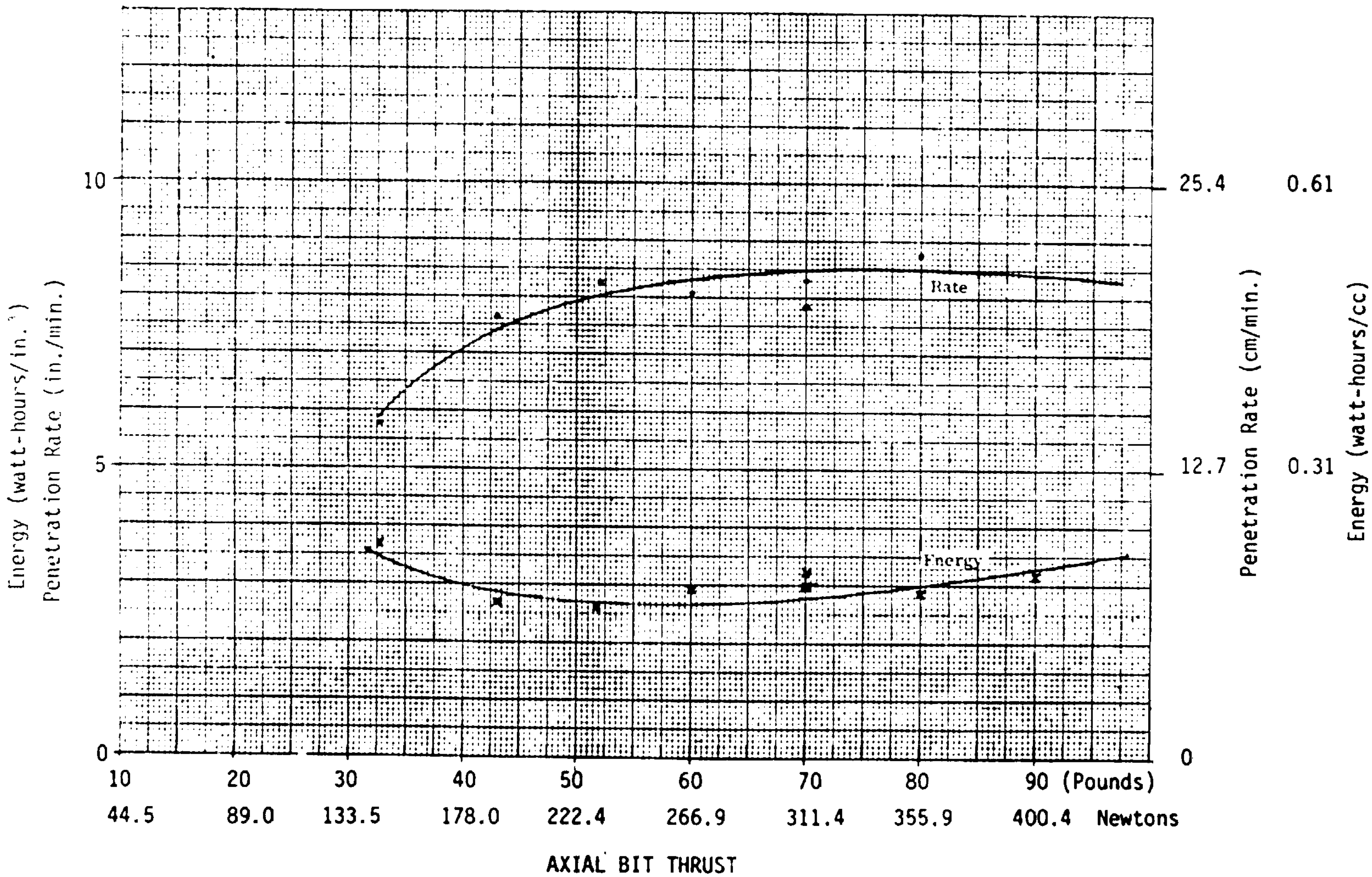


Figure 4-4 Projected Mars Drill Performance - 40% Porosity Basalt

5.0 SYSTEM DESIGN APPROACH

A potential design approach for a Mars roving vehicle-mounted drill system was considered at a *top level* only. Generation of detail conceptual design drawings were well beyond the scope of this program.

The generalized design approach is illustrated by use of a simple Mars roving vehicle mockup shown in Figures 5-1, 5-2, and 5-3. The conceptual drill system consists of the following elements:

1) Power Head -- provides the rotary-percussion energy for rock coring operation;

2) Guide Rail System and Drive -- provides power head restraint, guidance, and drilling thrust at controllable angles varying from perpendicular to parallel to the rover horizontal plane;

3) Turn-table and Drive -- provides repositioning capability of the drill (and robotic arm and camera) for operation in front of, to the left, or to the right side of the rover;

4) Core Bit and Tube -- provides the capability of drilling and storing the rock samples;

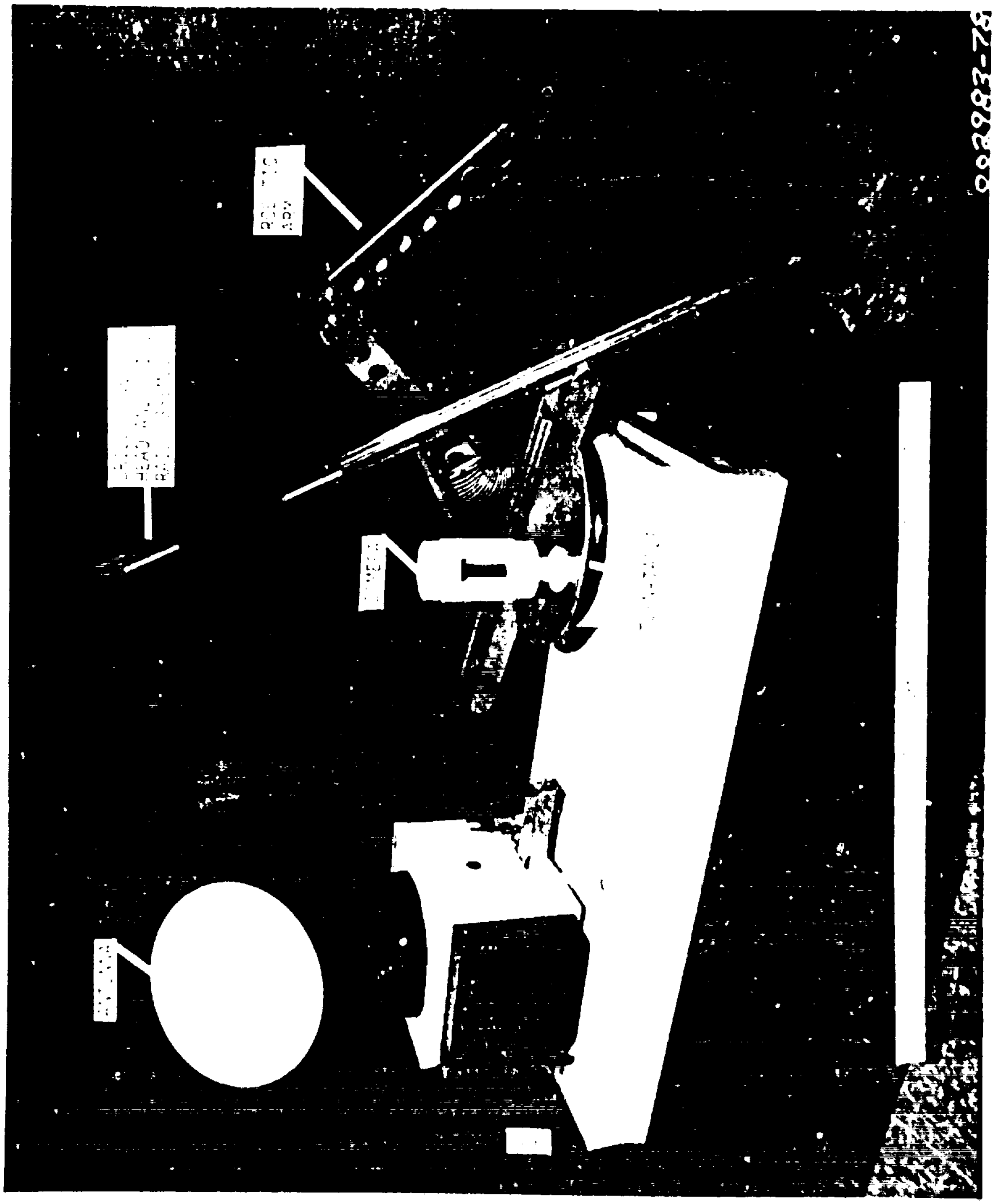
5) Core Tube Disconnect -- provides *disconnect* and *reconnect* capability;

6) I/O Electronics -- provides command and data control functions between the rover computer and the drill electromechanical components.

Core sampling is accomplished by positioning the drill (turn-table and guide rail) to align properly with the surface rock to be drilled. The power head is energized and appropriate axial drilling thrust applied. After completion of drilling, the power head is retracted and the drill is repositioned horizontally, as illustrated in Figures 5-2 and 5-3. The core tube disconnect device decouples the core bit and tube which are subsequently inserted into the core tube container (sample return container). The rotatable core tube container can subsequently be repositioned such that another empty core bit and tube can be withdrawn and coupled to the power head for acquisition of another sample.

A preliminary weight estimate for the system includes the following:

4.0 Kg -- power head
4.5 Kg -- guide rail system and drive
2.5 Kg -- turn-table and drive
0.3 Kg -- core tube disconnect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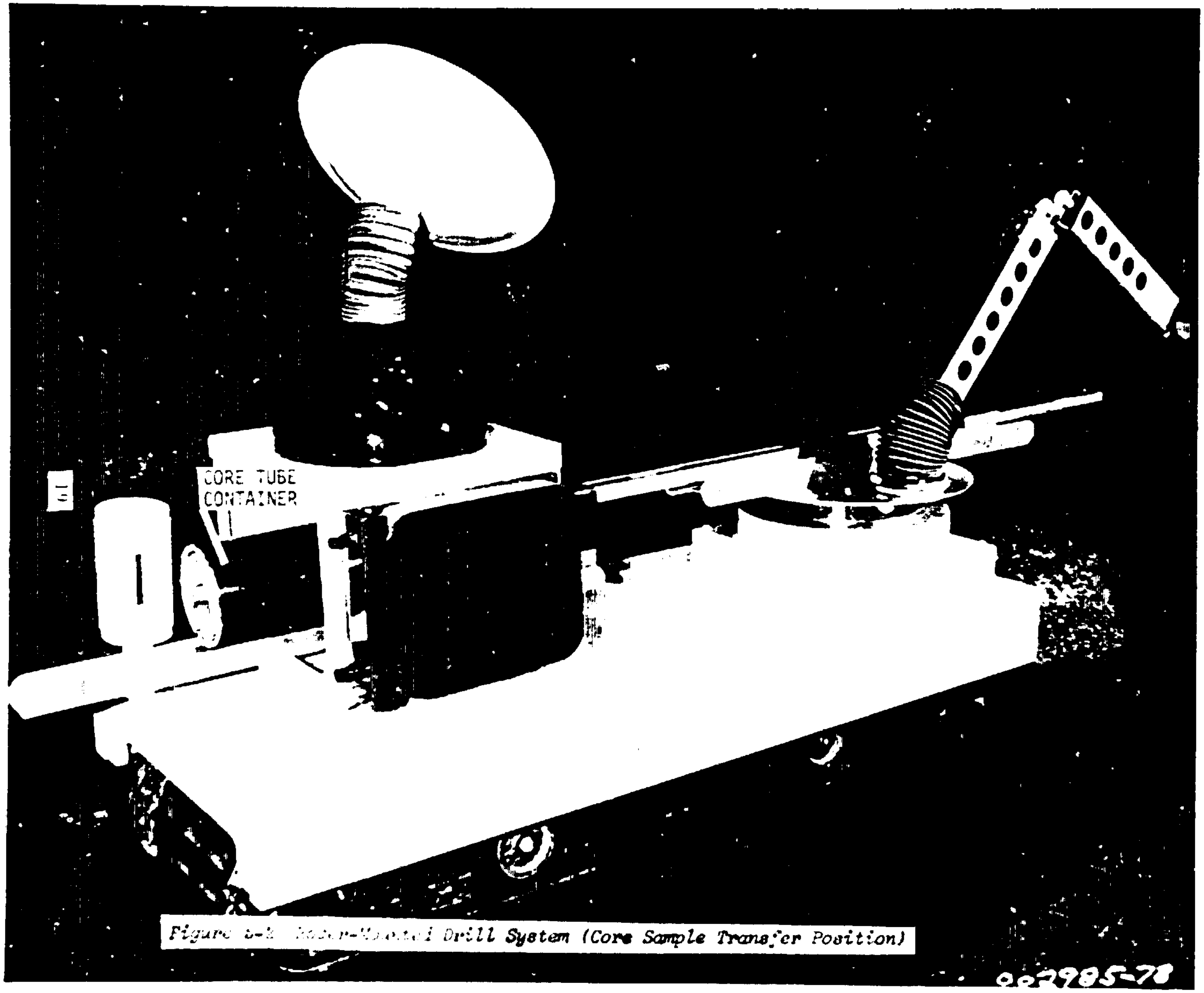

Figure 5-4 Rover-Mounted Drill System (Core Sample Transfer Position)

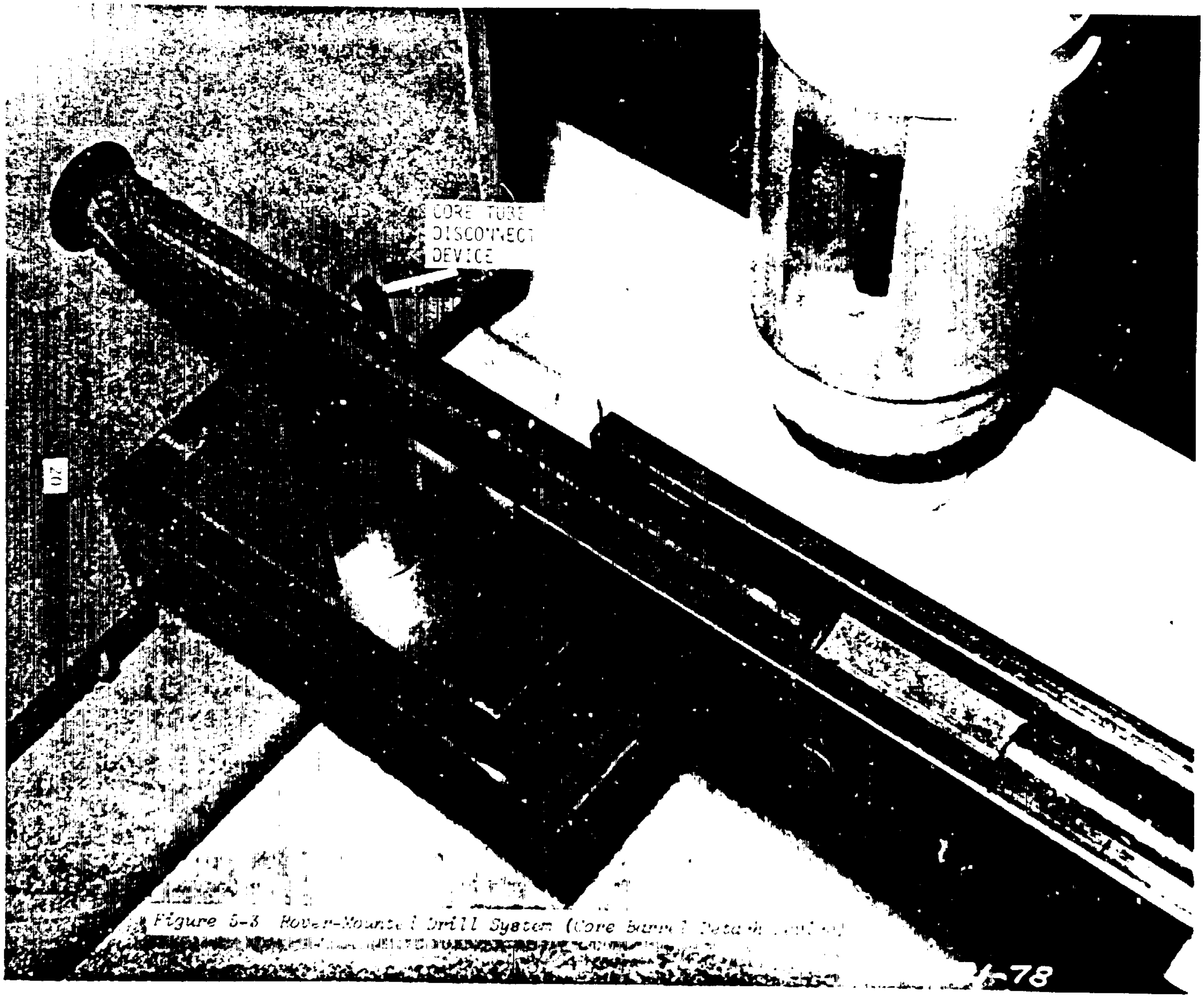

Figure 5-3 Rover-Mounted Drill System (Core Barrel

0.5 Kg -- each core bit and tube
3.0 Kg -- I/O electronics

14.8 Kg (32.6 lb) Total

6.0 RECOMMENDATIONS

This 4-1/2 manmonth program provided very preliminary data regarding a potential automated drill system for acquiring rock core samples from the Martian surface. However, an additional, more extensive effort is required to ensure that the total technology required for the drilling system is attainable within reasonable weight, power, complexity, and cost constraints. The total integrated sampling strategy (sampling acquisition techniques, sample return selection, preparation, handling packaging, sample return containers, etc) should be studied in detail. Last, but not least, the drillability/samplability of Mars-type permafrost (i.e., H_2O, CO_2) should be studied (and tested) if northern latitude operations on moderate depth samples are anticipated.

A two-phase follow-on effort is recommended which should be completed prior to finalization of sample return mission planning and configuration commitments. The first phase should consist of some limited tests, configuration analyses, and conceptual design. The second phase should consist of the design, fabrication and test of critical mechanisms associated with all aspects of the Mars sampling systems.

Specifically, the program should include, but not be limited to, the following:

1) Perform actual rotary-percussion drilling tests in simulated CO_2 and H_2O permafrost soil models;

2) Perform tradeoff analyses of all potential sampling acquisition and handling devices such as drills, sampling scoops, rock crushers, robotic arms, sample packaging, sample return containers, etc;

3) Generate top level layout drawings for the sample acquisition, handling, and storage subsystem selected from the previous task;

4) Perform analyses of design risk, weight, command and data management, and power requirements of the subsystems designed in the previous task;

5) Perform detailed design, fabrication, and test of critical mechanism breadboards.

The prime objective of the next Mars mission will probably be *sample return*. The sampling technologies and costs must receive extensive attention prior to final commitment.

7.0 REFERENCES

1. Martin Marietta Report No. ER 13952, *Final Report for Lunar Rock Coring Device Design Study*, dated October 1965, performed under NASA Contract No. NAS9-3542.

2. Martin Marietta Report No. ER 14[illegible]52, *Final Report for Design Study for Lunar Exploration Hand Tools*, dated December, 1965, performed under NASA Contract No. NAS9-3647.

3. Martin Marietta Report No. ER 14349P, *Phase C Final Report/Phase D Technical Proposal for Apollo Lunar Surface Drill (ALSD)*, dated August 29, 1966, performed under NASA Contract No. NAS9-6092.

4. Martin Marietta Report No. DPR-6-1, *Final Report for Apollo Lunar Surface Drill (ALSD)*, dated November 1, 1968, performed under NASA Contract No. NAS9-6587.

5. Martin Marietta Report No. D-69-84605-001, *Final Report, Orbital and Planetary Tool Development*, dated February, 1970, performed under Martin Marietta IRAD Task No. 605.

6. Martin Marietta Report No. MCR-70-429, *Feasibility Study Final Report for Improved Coring System for Apollo Lunar Surface Drill (ALSD)*, dated November 20, 1970, performed under NASA Contract No. NAS9-9462.

7. Martin Marietta Report No. MCR-71-318, *Apollo 15 Lunar Surface Drill Mission Performance and Post-Flight Analyses*, dated October 30, 1971, performed under NASA Contract No. NAS9-9462.

8. Martin Marietta Report No. MCR-72-201, *Apollo 16 Lunar Surface Drill Mission Performance*, dated July 31, 1972, performed under NASA Contract No. NAS9-9462.

9. Martin Marietta Report No. MCR-73-18, *Apollo 17 Lunar Surface Drill Mission Performance*, dated February 28, 1973, performed under NASA Contract No. NAS9-9462.

APPENDIX A--SCIENTIFIC COMMUNITY SURVEY FORM AND LETTERS

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas
77058

NASA

Reply to Attn of SN7-78-L185

Members of the Planetary
Science Community

Dear Colleague:

As you know, we have been working toward a Mars Sample Return Mission for the mid- to late-1980's. Enough progress has been made so that your help is now needed. First I will bring you up to date concerning the developing Mars program.

For the past year the Mars program has been carried as a joint venture between the Jet Propulsion Laboratory (JPL) and the Johnson Space Center (JSC). JPL has been performing the spacecraft design and mission analysis studies while JSC has been working on the science requirements and objectives. This total effort has been guided by a small steering group chaired by Arden Albee of Cal Tech. The prime objective of the past year's efforts has been to explore all options of Martian exploration. In that context several vehicles have been studied, including orbiters for communication and/or scientific observation, soft landers, hard landers, penetrators, sample return vehicles, rolling balls, airplanes, autonomous rovers as landed laboratories, and mini-rovers as sample getters. The potential scientific return of the various vehicles has been evaluated and preliminary cost estimates have been generated as part of the engineering study. Although all cost estimates are tentative, the chief conclusions are that any two-site Mars mission that seeks to answer many of the major scientific objectives concerning Mars will involve several vehicle types and will probably cost between $1 and $1.5 billion in constant 1979 dollars.

It is a significant finding of the past year's activities that a Sample Return Mission with a scientific orbiter (for global geochemical and geophysical observations) plus a set of hard landers or penetrators (for seismic, weather, and other network observations) costs about the same as a landed roving laboratory with the same associated scientific orbiters, and hard landers (or penetrators). We believe that this finding assures that the next mission to Mars will return Martian samples to Earth for intensive study in laboratories of Principal Investigators throughout the world.

It is clear that drilling will be important in any Mars Sample Return Mission. Cores recovered from the regolith will be essential in studying such processes and phenomenon as weathering, regolith dynamics, and the inventory and storage of volatiles. Core drilling of boulders or outcrops may be the best method of obtaining and returning igneous rocks (remember Viking's inability to collect a small igneous rock), which are essential as calibration points in Martian chronology and to understand the internal evolution of the planet.

We are funding Don Crouch of Martin Marietta (the people who built the Apollo drill and the Viking arm and scoop) to perform a study aimed at generating a conceptual design for a Mars drill. A portion of that study is to generate a definitive set of drilling requirements.

I request that you take a few moments to complete the enclosed data sheet. The data thus collected will form a key input in defining the requirements for rock and regolith drilling as part of a Mars Sample Return Mission.

Sincerely,

Michael B Duke

Michael B. Duke
Chief, Lunar and Planetary Sciences Division

Enclosure

MARTIN MARIETTA AEROSPACE

DENVER DIVISION
POST OFFICE BOX 179
DENVER, COLORADO 80201
TELEPHONE (303) 973-3000

June 19, 1978

Members of the Planetary
Scientific Community

Dear Colleague:

It is time that we planetary scientists and engineers reflect on the results of surface sampling operations performed on the surface of the moon and Mars in order to visualize sampling requirements for future missions to Mars. Bulk particulate samples, surface rocks, 40-65 centimeter drive-tube particulate cores and 3-meter powered drill cores were acquired on the lunar surface by the Apollo astronauts and returned to Earth. Samples from the surface of Mars were acquired by a maneuverable boom/collector head and analyzed by experiments located within the Viking lander. Although the Viking samplers performed exceedingly well for nearly two years on the Martian surface, there were occasions when the various principal investigators would have desired to acquire samples at depths greater than the 20-centimeters attained by the samplers.

I am sure that many of you, in retrospect, may have employed alternate approaches to the lunar and Mars sampling tasks. I served as the Martin Marietta project engineer for both the Apollo Lunar Drill and Viking Surface Sampler programs, and, in retrospect, would also have modified some of the design approaches employed in the flight hardware.

We are currently performing a small study program directed at determining potential sampling requirements and mechanization approaches for future Mars missions. The enclosed letter prepared by Dr. Michael Duke of the Johnson Space Center outlines some of the potential future Mars missions currently being studied by the NASA. It is our feeling that we should solicit the thoughts of all members of the planetary scientific community regarding the surface sampling task. Therefore, your preliminary suggestions regarding sampling and coring requirements, mechanization approaches, and sample analyses will be greatly appreciated. A simple form has been prepared for your use. I would appreciate it if you would return it to me as soon as possible to my Martin Marietta address.

Very truly yours,

Donald S. Crouch

Donald S. Crouch
Mail Stop D-0222

FUTURE MAR MISSIONS

DRILL SAMPLER SCIENTIFIC/OPERATIONAL REQUIREMENTS

Request By ______________________________ Date ________

Address: ______________________________

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Telephone: ______________________________

Brief Description of Experiment(s): ______________________________

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Drill Experiment Sample Requirements:

		Rock Sample (core or drilled)	Particulate Sample (core or drilled regolith)
CORE/HOLE REQUIRE.	Diameter		
	Depth or length		
	No. of holes (cores)		
	Separation distance between holes (cores)		
SAMPLE REQUIREMENTS	Number of samples		
	Size (volume)		
	Special requirements (i.e., allowable T rise, min/max core or particle size, etc.)		
	Other comments		

Auxiliary Drill Experiment (i.e., probe emplacement, surface physical properties, etc.): ______________________________

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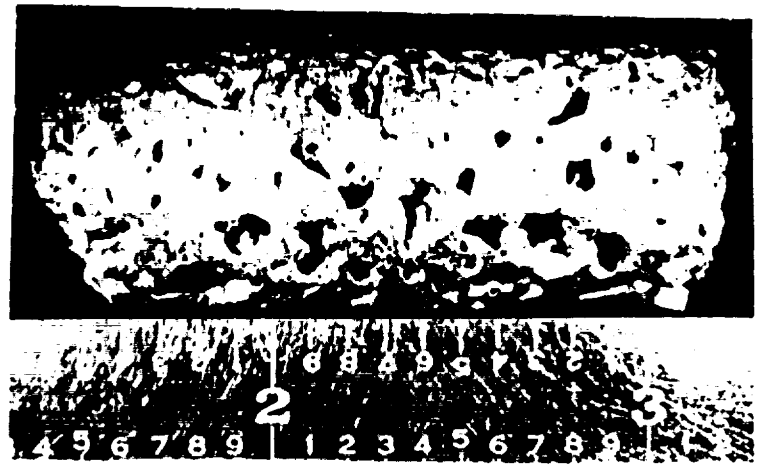
Suggested Earth Analog Test Suite Rocks

Type ______________________________

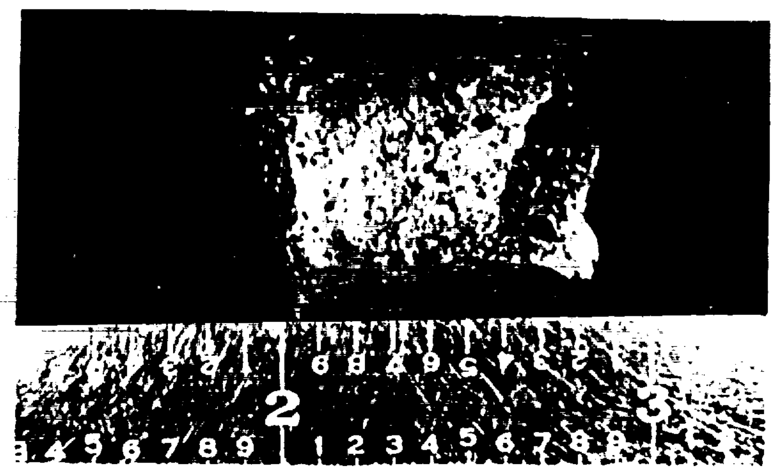
Location ______________________________

APPENDIX B--TYPICAL COMMERCIAL DRILL TEST RESULTS

A. Vesicular Basalt - Highly vesicular, fine-grained, porphyritic basalt with predominantly glass matrix. Phenocrysts represent small percentage of rock volume and are totally altered or missing. Vesicules represent 20-25% of the rock volume and show a continuous gradation in size from about 1 mm to 1 cm. (2.25X)



B. Vesicular Basalt - Highly dense, finely-vesicular, porphyritic basalt. Phenocrysts appear to be in hand examination composed of olivine and plagioclase feldspar. On small scale, rock is only finely vesicular, however, large rock sample exhibits large vesicules up to several centimeters in length. (2.25X)



C. Basaltic Scoria - Very fine-grained, scoratious basalt. Sample is highly fractured with about 20% vesicules by volume. (2.25X)

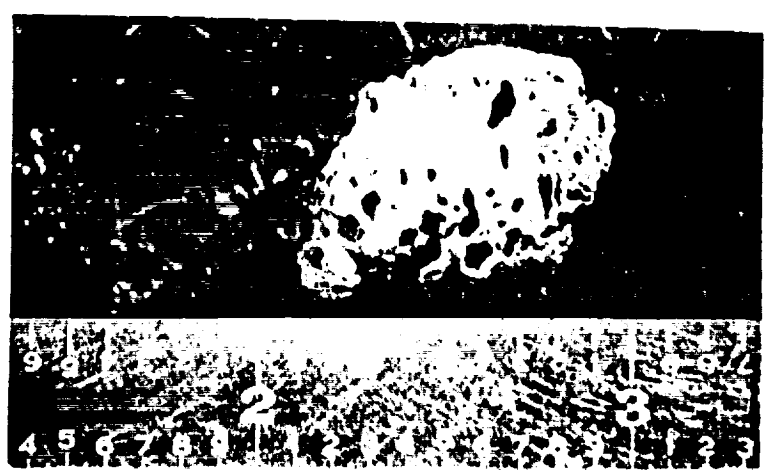


Figure B-1 Rock Sample Descriptions

ROCK DRILL TEST NO. 42

DATE: Nov. 1978

Rock Description: ROCK SAMPLE "A" VESICULAR BASALT.

Drill Description: BLACK-DECKER 3/8" HAMMER DRILL #5040

Drill Thrust: 20 LBS. Drill Bit Description: 1.9 CM. LUNAR CORE BIT

Test Duration: 60 SECS. Volts: 80 Amps: 2.9 Watts: 232/185

Watt-Hours required to displace one(1) cubic inch of rock: 41

Drill penetration per minute: 3/16" Approx. Core sample size: 3/4 DIA.

VTF CELL P-6 2ND FLOOR

Observations. WATT-HRS = 185 x .016 = 2.9

ROCK DISPLACED = .187 x .39 = .07 IN^3

WATT-HRS/IN^3 = $\frac{2.9}{.07}$ = 41

Test conducted for: D.S. CROUCH Test conducted by: D. CROUCH

ROCK DRILL TEST NO. 54

DATE: Nov. 1978

Rock Description: ROCK SAMPLE "C" VESICULAR

Drill Description: BLACK & DECKER 3/8 HAMMERDRILL #5040

Drill Thrust: 20 LBS. Drill Bit Description: 1.9 CM. LUNAR CORE BIT

Test Duration: 60 SECS. Volts: 80 Amps: 2.8 Watts: 224/179

Watt-Hours required to displace one(1) cubic inch of rock: 28

Drill penetration per minute: 1/4" Approx. Core sample size: FRAGMENTS

Location of test: VTF BLDG. CELL P-6.

Comments and Observations: APPROX. 450 RPM.

GOV'T. FURNISHED ROCK SAMPLE

WATT-HRS = 179 x .016 = 2.8

ROCK DISPLACED = .25 x .39 = .097 IN^3

WATT-HRS / IN^3 = $\frac{2.8}{.097}$ = 28

Test conducted for: D.S. CROUCH Test conducted by: M Clewett

ROCK DRILL TEST NO. 65

DATE: NOV. 1978

Rock Description: ROCK SAMPLE "B" HARD VESICULAR.

Drill Identification: BLACK-DECKER 3/8 HAMMER DRILL #5040

Drill Thrust: 30 LBS. Drill Bit Description: 1.9 CM. LUNAR CORE BIT

Test Duration: 60 SECS. Volts: 80 Amps: 3.6 Watts: 238/230

Watt-Hour required to displace one 1 cubic inch of rock: 52

Drill penetration per minute: 3/16" Approx. Core sample size: 3/4 DIA.

[illegible]: VTF BLDG. CELL P-6

Comments or Observations: APPROX. 300 RPM.

GOVERNMENT FURNISHED ROCK.

WATT-HRS = 230 X .016 = 3.7

ROCK DISPLACED = .187 X .39 IN^2 = .07 IN.^{3}

WATT-HRS./IN^3 = $\frac{3.7}{.07}$ = 52

Test conducted for: D.S. CROUCH Test conducted by: M. Clewett